Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1	("6829559").PN.	US-PGPUB; USPAT	OR	OFF	2005/08/17 15:17
L2	873	356/237.1.ccls.	US-PGPUB; USPAT	OR	ON	2005/08/17 15:17
L3	708	2 and @ad<"20021004"	US-PGPUB; USPAT	OR	ON	2005/08/17 15:33
L4	28	3 and (computer with implement$3)	US-PGPUB; USPAT	OR	ON	2005/08/17 15:19
L5	2204	(front adj side) and (back adj side) and (determin$5 or inspect$3) and defect	US-PGPUB; USPAT	OR	ON	2005/08/17 15:32
L6	103	5 and (computer with implement$5)	US-PGPUB; USPAT	OR	ON	2005/08/17 15:32
L7	72	6 and @ad<"20021004"	US-PGPUB; USPAT	OR	ON	2005/08/17 15:33

US-PAT-NO: 6134343

DOCUMENT-IDENTIFIER: US 6134343 A

TITLE: System or method for detecting **defect** within a semi-opaque enclosure

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Abstract Text - ABTX (1):

A method and system detect for the presence of a **defect** or a non-conforming object of unknown shape, configuration, and location within a semi-opaque enclosure. The semi-opaque enclosure has a pattern which is visible on at least a first of its external surfaces. The semi-opaque enclosure may comprise, for example, a labeled plastic or glass bottle, and the visible pattern may be print and graphical information provided on the bottle's label. A first digital image is captured from first channel light reflected off the first external surface of the enclosure; and a second digital image is captured from second channel light navigating the object inside the enclosure and emanating from the first external surface of the enclosure. A difference image is formed substantially devoid of information representing the visible pattern on the first external surface, by subtracting one of the first and second digital images from the other. Additional segmentation processing may be performed on the difference image in order to better identify the presence of a **defect** or non-conforming object within the semi-opaque enclosure.

Application Filing Date - AD (1):

19990407

TITLE - TI (1):

System or method for detecting **defect** within a semi-opaque enclosure

Parent Case Text - PCTX (5):

U.S. patent application Ser. No. 08/621,189, entitled "Machine Vision Methods for **Inspection** of Leads on Semiconductor Die Packages," filed in the name of Sanjay Nichani on Mar. 21, 1996;

Parent Case Text - PCTX (6):

U.S. patent application Ser. No. 08/621,190 entitled "Machine Vision Methods for **Inspection** of Semiconductor Die Surfaces," filed in the name of

Sanjay Nichani on Mar. 21, 1996;

Brief Summary Text - BSTX (6):
Computer vision, otherwise referred to as image processing, involves the extraction of vision-related information by obtaining signals representing a scene and performing image signal processing on those signals. Applications of computer vision (image processing) techniques include character recognition, industrial **inspection** of manufactured items, robot guidance systems, radiology, remote sensing, and so on.

Brief Summary Text - BSTX (13):
Golden Template Comparison (GTC) is an image processing method that has been used to detect flaws and **defects** in two-dimensional scenes of an **inspected** item which are highly repeatable and do not suffer from geometric distortion. Such scenes are common in semiconductor production and graphic arts applications. Generally, GTC involves the comparison of a test image to an image of a known good scene referred to as a template image. More specifically, the test image is subtracted from the template image, and differences between the two images are observed in order to **determine** whether a flaw or **defect** is present within the **inspected** item.

Brief Summary Text - BSTX (14):
Generally, GTC comprises two main phases: training and **inspection**. During training, the template image is constructed by sampling a plurality of images each of which represents a scene of an item absent **defects**. During **inspection,** the test image, which represents the scene of the item to be tested (the **inspected** item), is then compared to the template image. More specifically, the images are subtracted to form a difference image. Thresholding is performed on the difference image to produce a resulting binary image called an error image containing either background (healthy) pixels or **defect** pixels which represent flaws. The error image is then analyzed in order to **determine** whether the tested item should be labeled as an "accept" or "fail" item. The analysis that may be performed on the error image may include counting **defect** pixels found in the error image and performing a blob analysis on the **defect** pixels. The results of the analysis may be stored in a data structure called a results structure.

Brief Summary Text - BSTX (15):
A. Issues Concerning the Use of Golden Template Comparison to **Inspect** the Inner Side-Wall of a Labeled Bottle

Brief Summary Text - BSTX (17):

In order to produce (with thresholding) an error image which effectively and accurately represents **defect** pixels separate from healthy pixels, pixels within the difference image must have a sufficiently high gray level value. In order for this to occur, **defects** must give rise to a change in image intensity in the test image. In graphic arts applications, **defects** are typically defined in terms of changes in scene reflectivity, which result in a change in image intensity in the test image. Semiconductors are **inspected to determine** if they contain surface contaminants that can result in a subsequent device failure. Such surface contaminants frequently cause changes in scene reflectivity which thereby change the image intensity of the test image.

Brief Summary Text - BSTX (18):
In each of these situations, the **defect** is externally-visible. A problem arises, however, when **inspecting** semi-opaque enclosures (e.g., when **inspecting** the inner side-wall of a labeled bottle) to **determine** whether they contain unwanted objects (**defects**). In that application, the **defect** is not externally visible. Therefore, when **inspecting** the inside of semi-opaque enclosures for **defects** (non-conforming objects), it is difficult to obtain a test image that exhibits a change in image intensity due to the presence of a **defect**.

Brief Summary Text - BSTX (19):
(2) Gray-level **Defect** Criteria

Brief Summary Text - BSTX (20):
In order to produce an error image which accurately distinguishes **defect** pixels from background (healthy) pixels, thresholding may be performed in accordance with appropriate gray-level **defect** criteria. Various thresholding methods have been proposed which perform thresholding in accordance with different criteria. A simple type of **defect** criteria is photometric **defect** criteria which classifies pixels as background (healthy) pixels or **defect** pixels based upon image intensity alone. Other **defect** criteria (e.g., based on the shape formed by a group of adjoining **defect** pixels) can be utilized to guide the thresholding process.

Brief Summary Text - BSTX (21):
(3) Geometric and Morphological **Defect** Criteria

Brief Summary Text - BSTX (22):
The binary error image may be further processed to correct (replace) improperly classified pixels. For example, the binary error image may comprise **defect** pixels falsely classifying healthy pixels as **defects**. Accordingly, the binary image may be processed by imposing additional criteria, e.g., based,

upon the size and/or shape of a set of adjoining **defect** pixels. Simply put, **defect** pixels formed in the error image from small intensity variations in the test image may be ignored (i.e., replaced with healthy pixels) unless they represent a **defect** which is of a certain size and/or shape (e.g., if the **defect** is at least several pixels in length or diameter). Geometric and morphological **defect** criteria are disclosed by William M. Silver and Jean Pierre Schott in a document entitled "Practical Golden Template Comparison," provided by Cognex Corporation, the content of which is hereby incorporated herein by reference in its entirety.

Brief Summary Text - BSTX (23):
The usefulness of **defect** criteria (such as geometric and morphological **defect** criteria) can be significantly diminished when a distorted test image is acquired, e.g., by a conventional bottle **inspection** arrangement, as shown in FIGS. 7A-7C.

Brief Summary Text - BSTX (24):
A conventional labeled-bottle visual **inspection** system is shown in FIG. 7A which comprises a vertically-arranged, elevated camera 200 having a wide-angle lens 200a pointed directly into an upper opening of a bottle 202. Bottle 202 has a semi-opaque label 203 surrounding its outer side-wall surface 210, and is positioned over back lighting 206. A **defect** 204 is depicted in FIG. 7A with dotted lines, because **defect** 204 is not visible from outside of bottle 202 due to the opaque nature of label 203. **Defect** 204 is on an inner side-wall surface 208 of bottle 202, behind label 203. FIG. 7B comprises a cut-away view of bottle 202, in which inner side-wall surface 208 is exposed, and **defect** 204 is viewable. The view provided in FIG. 7B directly faces **defect** 204. As depicted, **defect** 204 is dark in appearance and rectangular in shape.

Brief Summary Text - BSTX (25):
FIG. 7C shows a 2D test image 201 which is acquired by camera 200 with the use of a wide-angle lens 200a. In order for the complete inner side-wall surface 208 which spans the entire area of label 203 to be **inspected,** wide-angle lens 200a is used which results in a distorted test image 201. The distorted nature of 2D test image 201 is evident from the relative positions of various portions of bottle 201 within the test image, including lower rim 212 of bottle 202, bottom edge 216 of label 203 and top edge 214 of label 203. The entire area of interest lies between bottom edge 216 and top edge 214.

Brief Summary Text - BSTX (26):
As shown in FIG. 7C, test image 201 includes a distorted depiction of **defect** 204. Due to the significant distortion of the shape and size of **defect** 204 in

the 2D test image 201 shown in FIG. 7C, it is difficult to define **defect** criteria which can be used to accurately identify the existence, size and position of **defects**. The above-described geometric and morphological **defect** criteria are not sufficient for this purpose.

Brief Summary Text - BSTX (28):
In performing training, a data structure is created containing information important for the subsequent **inspection** of a test image. The process includes acquiring several sample images taken under varying conditions, and then calculating statistics from data gathered in connection with the sample images. The calculated statistics include a template image which is the arithmetic mean of the several sample images. The template image is the image which is subtracted from the test image, and may be further used for purposes of normalization mapping. The calculated statistics also include a standard deviation image. This image may be used to derive a threshold image, which may be a linear mapping of the standard deviation image. Other statistics may be calculated from the acquired sample images for purposes of calculating a normalization map. Such statistics may include a histogram, mean, standard deviation, and left and right tails.

Brief Summary Text - BSTX (32):
These conditions cannot be met when **inspecting for defects** (or other non-conforming objects) within a semi-opaque enclosure such as a labeled bottle. In the conventional labeled bottle **inspection** system illustrated in FIGS. 7A-7C, the **defect** 204 is on an inner side-wall surface 208 of a bottle 202, hidden behind a label 203. Sample images, which would necessarily include an image of label 203, would not be repeatable. This is because the shape of label 203, which forms part of 2D test image 201, changes from bottle to bottle, due to typical variations caused when label 203 is applied to the outer side-wall surface 210 of bottle 203. In addition, 2D test image 201 is clearly distorted due to the use of a wide-angle lens 200a in acquiring the test image.

Brief Summary Text - BSTX (42):
A process of distinguishing between different types of regions within an image. Object/background discrimination is a particular type of segmentation which includes identifying those portions within an image corresponding to an object and those portions within the image corresponding to the background. **Defect** and flaw detection is a type of object/background discrimination.

Brief Summary Text - BSTX (44):
A process (commonly used in Golden Template Comparison flaw and **defect** detection methods) of obtaining a plurality (usually several) sample images of

flawless items to generate both a template image and statistical information pertaining to the template image.

Brief Summary Text - BSTX (48):
Another object of the present invention is to provide an improved segmentation method which can detect a **defect** (or another object of interest) of unknown shape, configuration, and location from within a semi-opaque enclosure of varying shape and configuration, such as a labeled bottle.

Brief Summary Text - BSTX (49):
A further object of the present invention is to provide an improved machine vision-based-**inspection**-system or method which facilitates an accurate interpretation of **inspection** results. More specifically, the machine vision-based **inspection** system or method detects **defects** with high sensitivity but with a decreased occurrence of false alarms, i.e., false "failure" indications.

Brief Summary Text - BSTX (50):
Other features may be provided to achieve yet additional objects and advantages. For example, a simplified template comparison segmentation technique may be provided which detects flaws and **defects** in a semi-opaque enclosure such as a labeled bottle. The simplified template comparison technique does not require high repeatability of the items being **inspected**; that is, the technique does not require that each item be identical. The simplified technique is thus appropriate for accurately

Brief Summary Text - BSTX (51):
detecting **defects** present on inner side-wall surfaces of labeled bottles or other **defects** within other types of semi-opaque enclosures.

Brief Summary Text - BSTX (52):
The simplified template comparison technique does not require training as do Golden Template Comparison and similar techniques. A template image is obtained almost simultaneously with the obtaining of the test image. More specifically, the template image is "dynamic" and corresponds precisely to the particular item being **inspected** at that moment.

Brief Summary Text - BSTX (53):
The present invention, therefore, is directed to a method or system for detecting the presence of a **defect** or non-conforming object (at least one) of unknown shape, configuration, and location within a semi-opaque enclosure. The semi-opaque enclosure may comprise a labeled plastic or glass bottle.

Brief Summary Text - BSTX (55):
A first digital image is captured from first channel light reflected off the first external surface of the semi-opaque enclosure. More specifically, the first digital image may be a reflected-light image formed with front lighting impinging on a **front side** of the rigid semi-opaque enclosure. A second digital image is captured from second channel light navigating the object inside the enclosure and emanating from the first external surface of the enclosure. More specifically, the second digital image may be a transmitted-light image formed with back lighting, which is directed onto a **back side** of the semi-opaque enclosure and thus forms a silhouette image of the object inside the enclosure. The silhouette image emanates from the first external surface (e.g., the **front side**) of the enclosure. A difference image is formed substantially devoid of information representing the visible pattern on the first external surface, by subtracting one of the first and second digital images from the other.

Drawing Description Text - DRTX (10):
FIG. 7A illustrates a conventional labeled-bottle visual **inspection** system;

Drawing Description Text - DRTX (12):
FIG. 7C depicts a 2D test image formed using the conventional labeled-bottle visual **inspection** system of FIG. 7A;

Drawing Description Text - DRTX (13):
FIG. 8 is a perspective view of an illustrative embodiment of a labeled-bottle visual **inspection** system which may be provided in connection with the present invention;

Drawing Description Text - DRTX (14):
FIG. 9 is a flow chart illustrating a visual **inspection** process which may be performed in connection with the visual **inspection** system shown in FIG. 8; and

Detailed Description Text - DETX (6):
Item 506 comprises part of a complete semi-opaque enclosure, such as an envelope or a labeled bottle, or another type of semi-opaque enclosure which may contain an object or a **defect** that is to be detected. In FIGS. 1 and 2, item 506 is a portion of an outer side wall of a labeled bottle; remaining portions of the labeled bottle have been omitted to simplify the explanation of the features depicted. The illustrated label includes the letters "ABC" printed on its outer front surface 508.

Detailed Description Text - DETX (9):

FIG. 3A illustrates reflected-light image 512, and FIG. 3B illustrates transmitted-light image 514. As can be seen in FIGS. 3A and 3B, each of these images includes the same background information, representing background print 515, while only transmitted-light image 514 includes an image of object 516. A difference image is shown in FIG. 3C. When one of the images shown in FIGS. 3A and 3B is subtracted from the other, the background information is removed, and only object 516 remains. Thresholding is performed on the gray-level difference image 528 shown in FIG. 3C, which causes a binarized image to be produced. Thresholding techniques that may be used will be further described below. A segmented binary image is thus produced that includes an accurate depiction of detected object 516. The binary image may contain a matrix of pixels, with **defect** pixels (e.g., "1's") representing detected object 516, and background (healthy) pixels (e.g., "0's") representing background information.

Detailed Description Text - DETX (12):
If a single threshold value is used to binarize difference image 528, errors will likely occur in the resulting segmented binary image 520. That is, the resulting binary image 520 would not likely represent an accurate segmentation. For example, if a single threshold value is set to a high value, for example, a value greater than 25, then the resulting segmented binary image 520 would include a number of broken/disjointed regions, i.e., regions within object 516 which would be inaccurately identified as part of the background. This would hinder the ability to identify object 516, or otherwise recognize it as a **defect**. If a single threshold value is set to a low value, then the system is susceptible to picking up shadows and other noise which are part of the background image and not part of object 516. Such shadows and noise can cause the apparent shape of object 516, as depicted in the resulting segmented binary image 520, to become distorted.

Detailed Description Text - DETX (23):
r=s.sup.2 t/1000, where t is a threshold coefficient which may be **determined** empirically.

Detailed Description Text - DETX (24):
Referring back to FIG. 4, once local threshold image 526 is obtained, thresholding mechanism 530 subtracts it from difference image 528. Thresholding mechanism 530 then binarizes the result using a map, such that pixels with positive difference values are replaced with a **defect** pixel (e.g., a "1") and pixels with a negative difference value are replaced with a background (healthy) pixel (e.g., a "0"). An exemplary resulting segmented binary image 520 is illustrated at the bottom of FIG. 4.

Detailed Description Text - DETX (26):

FIG. 5 is a perspective view of a bottle having a brand "A" soda label surrounding the bottle's periphery, attached to an outer surface of the bottle's side wall. A computer vision system may be utilized to detect whether an item located inside a semi-opaque enclosure, such as bottle 540, and (if desired) to identify the detected item. In the specific case of bottle 540, a soda company may wish to **inspect** the inside surface of bottle 540 to **determine** whether it contains any unwanted debris or matter. The semi-opaque enclosure (a labeled bottle 540 as shown in FIG. 5) allows visible light to pass through from one side of the enclosure to the other and to be detected by an image acquisition device such as a CCD (Charged Coupled Device). Accordingly, a reflected-light image and a transmitted-light image may each be obtained and utilized to detect (and optionally also identify) an item located within the semi-opaque enclosure.

Detailed Description Text - DETX (30):

FIG. 8 is a perspective view of a labeled-bottle visual **inspection** system 300. The illustrated system 300 comprises a vision control and processing computer system 302, an ensemble of bottles 306x (including the bottles 306a-306c shown in FIG. 8 and others (not shown)) supported by a conveyor 308, and various image acquisition components. A front light 312 is positioned in alignment with a vertical plane which is parallel to the direction of movement of conveyor 308.

Detailed Description Text - DETX (33):

As the ensemble of bottles 306x (including the three-bottle set 306a-306c, positioned between back light 310 and front light 312) moves along conveyor 308, transmitted-light and reflected-light images are obtained of the selected three-bottle set, each time the bottles are moved along conveyor 308 by a distance corresponding to one bottle. The table below illustrates the manner in which the necessary images can be obtained in order to **inspect** the complete inside and outside of each bottle. The illustrated labeled bottle **inspection** system 300 is capable of **inspecting** the complete insides of the bottles, including portions which are covered by a semi-opaque label, and is further capable of **inspecting** the outside surfaces of the bottles. In order to do this, three sets of images are taken for each bottle. A first set of reflected-light and transmitted-light (first and second) digital images may be obtained while a bottle is in a first orientation (rotated by 0.degree.), a second set of such images may be obtained while the same bottle is in a second orientation (rotated by 120.degree.), and a third set of such images may be obtained while the bottle is in a third orientation (rotated by 240.degree.).

Detailed Description Text - DETX (35):

When a three-bottle set is within the range of the image acquisition system, including front light 312, back light 310, and camera 318, a total reflected-light image (first digital image) is obtained which includes an image of the entire profile of all three bottles within the three-bottle set. Similarly, the transmitted-light image (second digital image) includes the complete profile of all three bottles within the three-bottle set. Conventional **inspection** processing methods may be performed to **determine** whether **defects** exist on the outer surfaces of the bottles. Similarly, in order to **inspect** the inner side-wall surfaces of the bottles at locations corresponding to transparent portions of the bottles (i.e., portions of the bottles not corresponding to the semi-opaque labels), conventional **inspection** processing methods may be performed.

Detailed Description Text - DETX (36):

In order to **inspect for defects** and non-conforming objects located behind a semi-opaque label, the pertinent portions of the overall bottle image (i.e., the pertinent portions of the first (reflected-light) digital image and second (transmitted-light) digital image) are obtained before subsequent processing is performed.

Detailed Description Text - DETX (37):

Sensor 314 is utilized to generate a signal when the position of a bottle corresponds to sensor 314 as it is moved by conveyor 308. Vision control and processing computer system 302 **determines** when a certain amount of time passes from the point at which the bottle passes sensor 314, in order to **determine** when a three-bottle set 306a-306c is in correct alignment with the image acquisition system. Accordingly, vision control and processing computer-system 302 facilitates registration of three-bottle sets with the image acquisition system.

Detailed Description Text - DETX (39):

The system illustrated in FIG. 8 may be modified and still facilitate thorough **inspection** of the inner side-wall surfaces of labeled bottles. For example, one or more cameras may be provided to capture first and second images, the bottles may be moved in a different manner, and may be rotated through less orientations. For example, two sets of images may be obtained for each bottle, by rotating a bottle from a first orientation (at 0.degree.) to a second orientation (rotated by 90.degree.). In addition, different lighting and/or mirror arrangements may be provided to effect the front and back lighting needed to produce the transmitted-light and reflected-light images.

Detailed Description Text - DETX (40):

Strobes 304a and 304b are provided to freeze the motion in the obtained images. They are controlled to correspond in time with the taking of the images by camera 318. This is done in order to prevent blurring in the resulting captured images. Movement of a bottle by an amount equivalent to one-half or more pixels can significantly blur the captured image. Bottles are typically moved in industrial settings at a fast pace, usually at 600 bottles per minute. Therefore, it is very important to take steps to prevent blurring of the captured images used for **inspection**. An additional, or alternate, measure that can be taken to reduce or eliminate blur is use of a shutter camera, which will localize (in time) the visual information which is used to capture each image.

Detailed Description Text - DETX (44):

FIG. 9 is a flow chart of the image processing which may be performed in connection with the visual **inspection** system illustrated in FIG. 8. A first digital image 330 and a second digital image 332 are each obtained for each orientation of each bottle. A registration mechanism 334 is provided to digitally register first digital image 330 with second digital image 332. Registration mechanism may perform such digital registration in accordance with a method utilizing two-dimensional cross-correlation of images as is disclosed by Jain in chapter 2 of a book entitled "Fundamentals of Digital Image Processing," Prentise Hall (1989). Chapter two of that book is hereby incorporated herein by reference in its entirety. Other additional or alternative digital registration techniques may be used at this point of image processing as well.

Detailed Description Text - DETX (45):

The registered images are then forwarded to first and second windows 336 and 338. First and second windows 336 and 338 obtain appropriate portions of the overall first and second digital images 330 and 332, for subsequent processing. When **inspecting** a labeled bottle, as illustrated in FIG. 8, the portion of the image obtained by the first and second windows 336 and 338 corresponds to the portion of bottle covered by a label. After windowing the first and second digital images with first and second windows 336 and 338, the resulting gray-level windowed first and second digital images may be normalized by first and second normalization mechanisms 340 and 342.

Detailed Description Text - DETX (52):

Upon receipt of a binarized error image output by binarization mechanism 348, an interpretation mechanism 350 analyzes the various **defect** pixels in relation to background (healthy) pixels in order to **determine** whether the

inspected item should be categorized as either an acceptance or a failure item. The interpretation processing may be implemented by simply counting the number of **defect** pixels present in the error image and/or by utilizing Blob analysis. These techniques are well-known in the art, and therefore are not discussed in detail herein.

Detailed Description Text - DETX (55):

By way of example, the vision control and processing **computer** system 302 may be **implemented** with a VME bus-based vision system, such as a Cognex 5400.

Other Reference Publication - OREF (1):

Automated Vision System for **Inspection** of IC Pads and Bonds, Sreenivasan et al., IEEE Transactions on Components, Hybrids, and Manufacturing Technology, pp. 335-338, vol. 16, No. 3, May 1993.